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A Comprehensive Literature Review on The Solar Drying Systems

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ABSTRACT

Since the cost of electricity is rising, and people are becoming more conscious of their desire to buy environmentally friendly items, solar dryers are quickly replacing traditional mechanical dryers. Experiments on drying thin layers of agaricus bisporus mushrooms have been conducted across three distinct types of inexpensive solar dryers: the "natural convection dryer (NCD), the forced convection dryer (FCD), and the heat pump integrated dryer (HPD)". In recent years, solar dryers have gained popularity as an eco-friendly replacement for traditional dryers that use fossil fuels. In contrast, solar dryers need a lot of time to dry anything since the sun doesn't always shine. This paper deals with the review of such research works which have been conducted to enhance the efficiency of the solar dryers.

Keywords: solar dryers, natural convection dryer, forced convection dryer, heat pump integrated dryer

INTRODUCTION

Even on gloomy days, energy may be collected from the sun. More and more people are turning to solar power to meet their energy needs, whether it be to power their homes or to desalinate their drinking water. There are two basic methods of producing solar energy: Photovoltaics, commonly known as solar cells, are a kind of electrical device that can convert sunlight into energy. Solar panels on homes and calculators both utilise current solar cells, so it's possible that most people have seen a picture of one before. U.S.-based Bell Telephone Laboratories is credited with inventing them in 1954. Currently one of the most rapidly expanding renewable energy technologies, PV is poised to play a significant part in the future global power generating mix.

Power from the sun may be generated in large-scale commercial arrangements, or in more modest mini-grids or even for individual homes. Mini-grids powered by solar photovoltaic systems are a great solution for providing electricity to remote areas without the need for large-scale infrastructure upgrades, especially in developing nations with abundant solar energy resources. Solar panels have become not only inexpensive, but frequently the cheapest type of power due to a substantial drop in the cost of manufacture over the last decade. Solar panels have a 30-year average lifetime and a wide range of colours and textures to choose from.

Mirrors focus the sun's beams to create concentrated solar electricity (CSP). The fluid is heated by the rays, turning into steam that then powers a turbine to produce energy. Large-scale power plants use CSP for energy generation. Typically, a CSP power station will include a field of mirrors which will reflect the sun's rays onto a tall, thin tower. The ability to store heat in the molten salts gives CSP power plants a significant advantage over solar PV power plants since they can continue producing energy long after the sun has set.

Most applications that need high temperatures for drying may benefit from solar heating. Solar dryers make use of air heated by the "solar energy collectors", that can be set up in the modules according to hot air needs. Using the sun to dry clothes is a straightforward idea. The dimensions of solar collectors are a key component of the solar drying systems. Collectors need to be able to provide the drying chamber with appropriate amounts of hot air based on the volume of objects to be dried. Collectors that are inadequate in relation to the quantity of food to be dried will inevitably lead to wasted effort and food.

LITERATURE REVIEW

[1] (Mani & Thirumalai Natesan, 2021) Under the same circumstances, the research compares the passive and active thermal performance of even span as well as "parabolic roof type solar greenhouse dryers". The 200-m UV-stabilized polyethylene sheets were used to cover dryers in order to maximise the drying impact of the sun's rays. The effectiveness of various dryers in curing lima beans is assessed (Phaseolus lunatus). The Lima beans' original 75% (w.b.) moisture content was lowered to 11%. (w.b). The parabolic drier could dry in 28 hours under active mode and 32 hours under passive mode, whereas the even span dryer would take 32 and 36 hours to get to the same point. Lima beans dried under the open sun for as long as 40 hours. Parabolic dryers operating in active mode were predicted to have a thermal efficiency of 14.7%, with even span dryers operating in passive mode having a thermal efficiency of only 12.03%. The payback time for the parabolic active mode dryer was just 2.15 years, compared to the dryers' estimated solid life duration of 10 years; hence, the usage of these dryers is strongly suggested for the small-scale, economically-disadvantaged farmers.

[2] (Chavan & Thorat, 2021) Solar Conduction Dryers, a newly marketed and patented design, were compared to the most popular solar dryers, which all have different basic designs based on different fundamental principles of mass and heat transmission. Drying load was bottle gourd, which weighed 100 kilogrammes (kg), had a starting moisture content of 80 percent, and needed 77.78 kilogrammes (kg) of water removed to reach the target moisture content of 10 percent. There were three metrics used to compare the effectiveness of different solar dryers: annualised cost, present value of yearly savings, and present value of cumulative savings. The lifetime annual savings for the drying bottle gourd are estimated to be 42,294, 23,027, 55,451, 58,740, & 37,594 USD for the solar cabinet dryer, solar tunnel dryer, corrugated solar conduction dryer, solar conduction dryer, and corrugated as well as electrically backed solar conduction dryer, respectively, according to the economic analysis. Dryer economic metrics like payback time and internal rate of return were also assessed. When comparing solar dryers on the basis of economics & product quality parameters, the study demonstrates that the "corrugated solar conduction dryer" (CSCD) provides the greatest performance.

[3] (Dake et al., 2021) In recent years, solar dryers have gained popularity as an eco-friendly replacement for traditional dryers that use fossil fuels. In contrast, solar dryers need a lot of time to dry anything since the sun doesn't always shine. Using sorption materials to improve solar dryer efficiency is discussed. The most important features of their function as "thermal energy storage" or "dehumidification materials" are emphasised. The report reveals that silica gel, among other solid adsorbents, dominates the market. Bentonite, $CaCl_2$, vermiculite, as well as cement are only few examples of composite materials that have shown promise in recent years. Drying times may be reduced by 15-30% when a sorption dehumidifier is included into a solar dryer (often at the solar collector input), with reported values as high as 50% and 64%. However, sorption materials included as thermal storage in a solar dryer, typically placed at the top of the drying chamber, often result in a decrease of drying time within the range of 30–45%. Before these methods can be used on a broad scale in sun drying technology, there are a number of questions that need answering.

[4] (Mohana et al., 2020) Due to the continuing energy shortage, renewable energy sources are desperately needed. Renewable energy sources should be considered for use in the food processing industry as an alternative to traditional, high-energy-consumption unit processes, such as drying. In terms of cost-effectiveness, energy efficiency, as well as rural application, food drying using solar energy is still an appealing option. However, there is a significant technology gap; it is difficult to design inexpensive and effective dryers for the mass production of safe, nutritious food. The efficient use of thermal energy requires careful consideration in the solar dryer's design as well as component selection. In light of these factors, this study compiles a description of several dryer applications for various foods, as well as a comprehensive analysis on the many dryer designs now available. In addition, new developments, problems, and limits in technology, energy concerns, and other socioeconomic elements for implementing the large-scale sun drying of foods are given. In light of this, this study sheds light on the current status of solar dryers, contributing to the development of an environmentally friendly and sustainable technology for use in the food industry.

[5] (Kumar & Singh, 2020) With solar drying, the moisture content of the items is reduced down below the point of no more product degradation. Direct solar dryers, indirect solar dryers, and mixed-mode solar dryers come in a wide range of sizes, capacities, and designs, but they all rely on the sun to dry their contents. The primary objective of this research was to compare and contrast the various solar dryer designs based on product-specific factors as well as

technical, economic, and ecological considerations. Research has shown that air temperature as well as velocity are the most important factors in determining the drying rate and efficiency of a solar dryer, followed by the solar radiation, product type, beginning moisture content, total product mass, as well as "thermal energy storage" materials. The product may be dried in a variety of methods, such as by utilising fossil fuels, solar radiation, a hybrid drying system, etc. Using fossil fuels presents a number of issues, including resource scarcity, high costs, and environmental damage. There are several problems associated with open sun drying, such as exposure to dirt, rain, wind, insects, human and animal intervention, and so on. When compared to other types of solar dryers, the mixed mode solar dryer that makes use of "thermal energy storage" materials is among the most effective and fastest.

[6] (Aramesh and Shabani, 2020) Evacuated tube solar collectors (ETSCs) have gained a significant share of the solar thermal collector (STC) market. Compared to other collector types, ETSCs cover a relatively wide range of operating temperatures, mostly offer higher thermal efficiency, and are available at reasonable prices. But similar to other solar energy technologies, ETSCs are suffering from two main drawbacks associated with intermittency of solar radiation. Phase change materials (PCMs) have been widely used to overcome this challenge. If properly designed and utilised, PCMs can reduce the energy fluctuations and store the solar thermal energy during the daytime and release it in the absence of sunlight. There have been many studies conducted on the integration of PCMs with ETSCs, but the lack of a comprehensive systematic review study focused on such integrated energy systems has remained to be a gap in the literature. This gap is addressed by the present review study. Based on both theoretical and experimental results reported in the literature, the present study focuses on PCM assisted ETSC systems from different perspectives such as integration types, design parameters, and performance. Four main types of integration between PCMs and ETSCs are identified and advantages and disadvantages of each type compared to the others are discussed. Furthermore, state of the art is also clarified, the knowledge gaps are identified, and a roadmap for further studies on these energy systems is provided accordingly.

[7] (Tegenaw et al., 2019) This study utilises both CFD and lumped capacitance modelling approaches to simulate the "transient heat transfer" in a solar food dryer. The dryer's airflow and "transient heat transfer" are simulated with the use of a CFD model. Energy exchanges between the drying chamber's numerous components inspired a "lumped capacitance model", which is contrasted at length with the CFD model's output. Both models agree that there will be a steady-state temperature increase of 40 C in the drying chamber. The two models' predictions of the transient temperature before reaching this point differ by roughly 8 °C RMS. The heat transmission coefficient near the shelves of the refrigerator is mostly responsible for this discrepancy. When these coefficients are fitted, the two models' mean temperature differences on the bottom and top shelves of the rack are only 1.8 and 0.9 degrees Celsius, respectively. By confirming the basic premise of the lumped capacitance modelling, CFD simulations of rapid heat transfer phenomena shown that temperature distributions are uniform 30 minutes after the event. This illustrates that the computationally intensive CFD modelling approach may be replaced by the simpler "lumped capacitance model" for forecasting transient heat transport phenomena in the solar food dryers.

[8] (Rodriguez, 2018) The canton of Jipijapa displays an annual radiation of 4.8 kWh/m2 day, making solar energy one of the most widely available renewable energy sources. This may be put into practise for various energy needs due to being a clean energy that can be sustained over time. Citizens of Cerro Grande, a town 529 metres above sea level, work in agriculture, notably the resurgence of the production of high-quality coffee prized for its flavour and fragrance. Due to insufficient drying methods, the price of green coffee beans has fallen on both the domestic and global markets. In an effort to improve the product's drying quality, and in light of the fact that bamboo cane (Angustifolia Kunt) is a resource with good energy properties, two dryers were designed to make use of direct and indirect solar energy, with the goal of determining which is best for drying coffee beans in an eco-friendlier and less labor-intensive manner. In light of the findings from its design, construction, and evolution, it has been determined that this type of drier can be implemented in communities with the conditions of the natural renewable resources as well as needs to enhance the drying conditions of different agricultural products, thereby supporting the energetic as well as social sustainability of the populations which live in rural areas and that today are the base of sustenance of agricultural products like cocoa, coffee,and others

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TYPES OF SOLAR DRYERS

There are two general types of solar dryers: Direct and indirect.

1. **Direct**

Drying equipment that uses direct sunlight to remove moisture does just that. Lines were strung between trees or rocks, or clothes were spread out on the roof of a tent to dry in the sun. The roof of the ger (tent) is historically used as a sun drier to preserve cheese and meat in Mongolia. Wind is used to shift the more humid air away from the objects being dried, enhancing the drying effect of the sun. Complex drying racks as well as solar tents have been built as sun dryers in recent years.

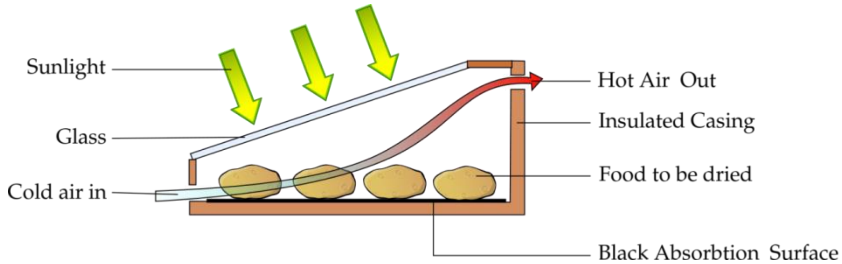

Figure -1 Direct Solar dryer

The material to be dried is put directly on a contemporary solar dryer's black absorbent surface, which gathers the light and transforms it to heat. Enclosures, glass covers, and/or vents may be added to these dryers to improve their performance.

2. **Indirect**

Instead of directly heating the product to be dried, the black surface of indirect solar dryers warms the incoming air. After being heated, the air is passed over the item to be dried and then, often via a chimney, the air is discharged upward, carrying the now-dry material and any remaining moisture with it. An insulated brick structure with an active ventilation as well as a backup heating system is on the other end of the spectrum from a plain tilting cold frame covered in black fabric. A benefit of the indirect technique is that it's less of a hassle to prevent the food or other product from being contaminated by the elements or by animals. Not only that, but certain foods' chemical makeup may change when exposed directly to sunlight, making them less tasty.

When using solar energy, the ideal drying temperature range is between 50 and 70 degrees. Polycarbonate sheets or UV preventative glass are used in modern solar dryers like the Vyom to block the sun's harmful UV rays from reaching the food being dried. When using a solar dryer, not only does the drying go more quickly, but also dust, bacteria, bird droppings, and other external factors that lower food quality are kept out of the equation. Dried fruits, spices, vegetables, as well as other foods may be kept for much longer in storage if exposed to sun radiation.

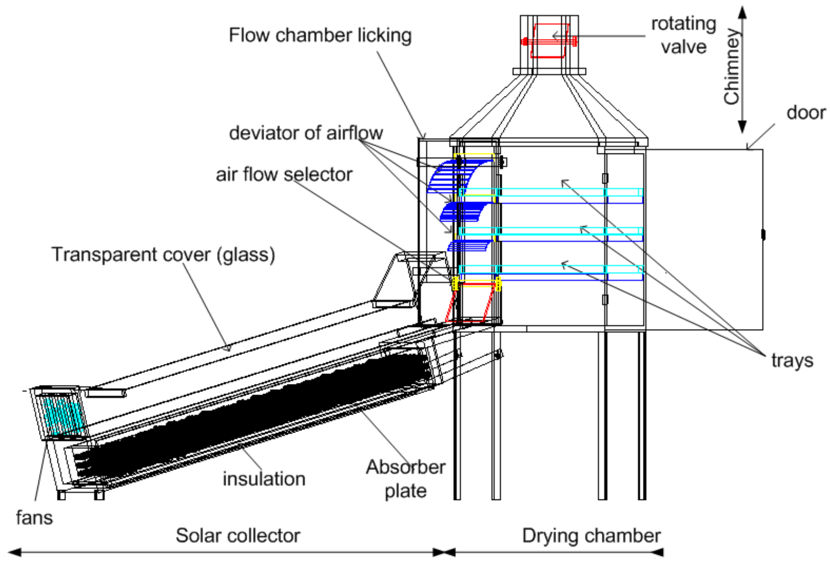

Figure -2 Indirect Solar Dryers

Indirect solar dryers may be found in several forms. There are essentially three types of solar dryers, and they are as follows:

- **Natural convection dryers**

Solar dryers that make advantage of the rising hot air (vertical convection) are now under development. As a rule, "natural convection dryers" are scaled down to fit the needs of a farm. The building's primary features are a solar collector, a drying bin, and a solar chimney. Smaller-scale natural convention dryers are just wooden boxes with top and bottom vents. Put the food on the screen frames and slide them into the boxes. The boxes are equipped with solar air heaters of the appropriate size, with plastic glass facing south as well as a black metal absorber. The solar air heater has a black metal absorber at the bottom that warms air coming in. As the air becomes warmer, it rises, pushing the food up and out of the top vents. Operating at temperatures between 130 and 180 degrees Fahrenheit (54 and 82 degrees Celsius), these dryers are ideal for drying and pasteurising a wide variety of foods. Even if it's misty and humid outside, you can dry food in only one day using one of these dryers. There are 13 shelves within, and they can each accommodate 35–40 medium-sized apples or peaches in thin slices.

- **Forced convection dryers**

A fan is used to blow the convection air directly onto the meal. Dryers that use forced convection might have a similar framework. But the forced convection drier needs electricity to run the fans that generate the air currents. The forced convection dryer's collector doesn't have to be angled in any particular direction for air flow; rather, it may be laid flat with the fan on one end as well as the drying bin on the other. Since the forced convection drier generates its own air flow, it may function in less-than-ideal weather situations when the "natural convection dryer" would fail. It is crucial to achieve optimal ventilation in the solar food dryers since poor ventilation is the major source of food loss and is exacerbated by the intermittent heating. Preventing spoilage is as simple as installing a fan or PV-solar cell to create a forced convection flow.

- **Tunnel dryers<**

A tunnel dryer has a straightforward construction. A tunnel dryer consists of the following primary parts:

A poly house-framed structure covered in UV-stabilized polythene sheeting to create a semicircular solar tunnel.

In contrast to several other dryer designs, this one really has room for a human inside.

Important quality factors

Food production cannot proceed without drying. The major benefit of drying food is that it may be stored for longer. Nevertheless, it's worth noting that the technique isn't primarily focused with drying out the food. The choice of the drying conditions as well as equipment also affects the following quality factors:

- **Moisture Content.** After drying, the food must be at a moisture level that allows it to be stored. The ideal moisture level of stored food varies with the kind of food, the length of time it will be stored, and the circumstances under which it will be stored. Under-dried food in a batch might ruin the whole thing, so it's important to dry everything evenly.
- **Nutritive value.** When food is heated to dangerous levels, it may damage its contents.
- **Mould growth.** Moisture, temperature, and the extent to which the food has been physically damaged all have a role in how quickly microorganisms may multiply on it.
- **Appearance and smell of the food.** For instance, if the paddy is dried using direct heated dryers with badly maintained or operated burners or furnaces, the milled rice may turn out an undesirable colour.

Classification based on the design of the Solar Dryer

- **Integrated solar dryers**

One kind of solar dryer is called an "integrated solar dryer" because it combines the solar energy gathering and drying processes into a single device. Common examples are multi-rack dryers, tunnel dryers, greenhouse dryers, as well as cabinet dryers. Compact and freestanding, these dryers are the norm.

- **Distributed solar dryers**

A distributed solar dryer is one in which the collecting and drying of solar energy happen at different facilities. The solar dryer consists of two sections: the drying chamber and the "flat-plate air heater". The flat-plate heater may be installed on the ground or the roof to warm the air around the structure. A fan is used to push the hot air from the air heater around the drying chamber. Depending on the required drying time, product type, airflow rate, and hot air temperature, these dryers may be built in a wide range of sizes and combinations.

- **Mixed-mode solar dryers**

Mixed-mode solar dryers absorb solar energy in both the air heater as well as the drying unit, but do all of their drying in the latter. These solar dryers capture sunlight from the outside using flat-plate solar collectors as well as the drying chamber's roof. Solar-heated air is often coupled with conventionally-heated air in big industrial drying systems to increase system dependability and dramatically cut traditional energy use.

CONCLUSION

In this paper tries to take a look at the many different approaches to solar dryer system modelling that exist. In order to design, optimise, analyse, and anticipate the performance of various sun drying systems, modelling approaches are essential. Predictions of crop temperature, moisture content, drying pace, quality, and colour all benefit greatly from the modelling methodologies. There are several problems associated with open sun drying, such as exposure to dirt, rain, wind, insects, human and animal intervention, and so on. When compared to other types of solar dryers, the mixed mode solar dryer that makes use of "thermal energy storage" materials is among the most effective and fastest.

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